water facts

No. 1

Ground Water in Fractured Hard Rock

In mountainous areas of California, groundwater can be found in the cracks or fractures of hard rocks, such as granite, greenstone, and basalt. The water does not actually penetrate the rocks, because there is no pore space between the grains of the rock. However, some of these rocks have fractures in them. These fractures store water and yield small amounts of water to wells that intersect the fractures. Some sedimentary rocks, like sandstone, are hard but can still absorb some water into their pores. These rocks may also have fractures that contain water. About 60 percent of California is composed of hard rocks. However, only a small quantity of groundwater is stored in the fractures of these rocks. The majority of groundwater is stored in what the average person would call "dirt" or "soil," more accurately described as alluvium (loose gravel, sand, and silt) which has pore spaces between the grains.

Where do you find hard rocks?

In general, all mountain and hilly areas of California are composed primarily of hard rocks. For instance:

- the Coast Ranges and large areas of coastal southern California and southern desert regions consist of granitic and metamorphic, volcanic, and hard sedimentary rocks;
- the Sierra Nevada is composed mainly of granite, but there are smaller quantities of volcanic, sedimentary, and metamorphic rocks; and
- the northeastern part of California is composed mainly of volcanic rocks.

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A thin layer of sediments, soil, or weathered rock covers some of these hard rock formations.

How do rocks get fractured?

Like most fractures, rock fractures are caused by stress. Rocks may fold, faults may move, and rocks may expand when overlying material is removed by erosion and the now-bare rocks are exposed to the weather. Volcanic rocks may also fracture while cooling and contracting. Ice, plant roots, or water flow can enlarge these fractures.

What do the fractures look like?

Fractures may be large or small and may run up and down or sideways. They may be a few millimeters to hundreds of meters long, and range in width from less than a millimeter to several centimeters. In carbonate rocks (limestone and dolomite) the fractures may be enlarged into caverns when the rock is dissolved by water. You'll find most fractures in the upper few hundred feet of rock. This is because the weight of the rock on top inhibits the development of deep fractures. In addition, the deeper you go, the smaller the width of these fractures. The beautifully sculpted rocks that form Yosemite Valley are the result of glaciation and the removal of rock material along these intersecting fracture surfaces.

What is the hydrologic cycle?

All moisture on Earth is in constant motion. The moisture nearest the Earth's surface is involved in what is called the “hydrologic cycle.” In this cycle, water evaporates from large bodies of water, such as oceans, lakes, and rivers, and is transported as water vapor to a different location where it is deposited as rain, snow, hail, or droplets of fog. Water that falls on land may run off on the surface in creeks and rivers, or it may infiltrate into the rock materials on the ground. It is this infiltration of water that recharges groundwater supplies in sandy, loose material and in fractured hard rock.

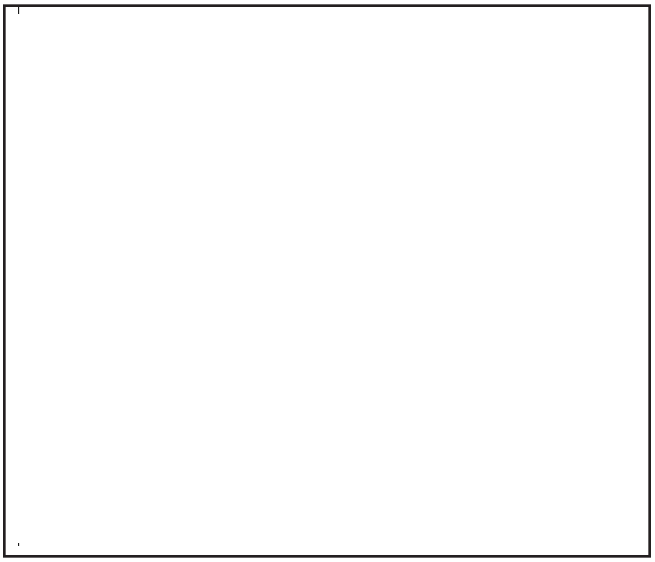
What is the relationship of fractures to groundwater?

For the most part, fractures are the only way groundwater can be stored in hard rocks. How much water you can get out of the hard rock depends on:

- size and location of the fractures;
- interconnection of the fractures; and
- amount of material that may be clogging the fractures.

Water can also be stored in lava tubes in volcanic rock and in solution openings in carbonate rocks (limestone and dolomite).

The Hydrologic Cycle

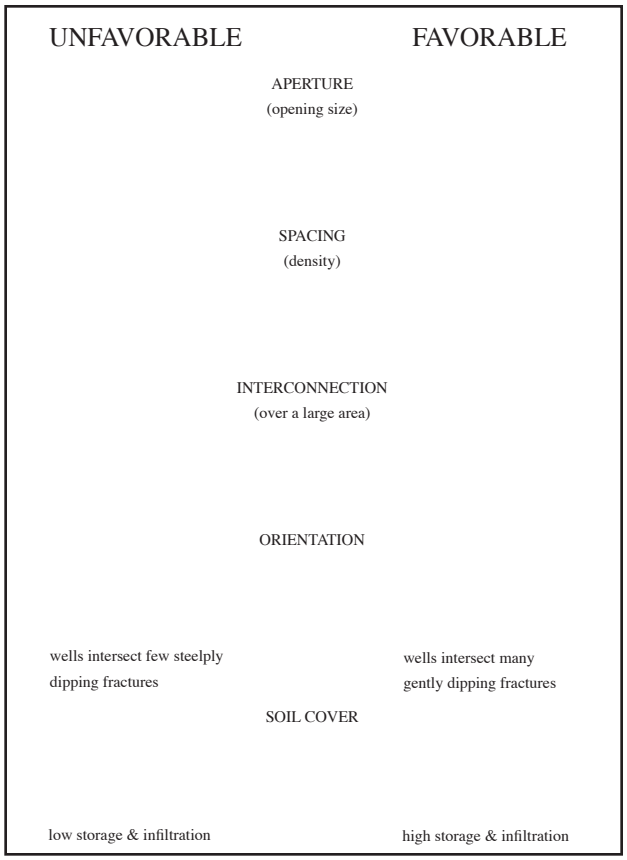


How much water is stored in hard rock?

The volume of water stored in fractured hard rocks near the surface is estimated to total less than 2 percent of the rock volume. This percentage decreases with depth as fractures become narrower and farther apart. The total amount of water in storage in the rocks surrounding a hard rock well is small, so that groundwater levels and the well’s yield can decline dramatically during the summers of dry years. The volume of water stored in many alluvial soils can amount to 10-25 percent of the volume of the alluvium. In areas

where alluvium overlying the hard rock is saturated with water, the alluvium provides additional water storage for nearby wells in the hard rock. This situation most often occurs in valleys or meadows.

Fracture Characteristics Controlling Ground Water Availability



How much water will your well yield?

Half of all hard rock wells yield 10 gallons per minute or less, which is only enough for individual domestic supplies. When conditions are good, wells drilled in fractured rock may yield several hundred gallons per minute when pumped. Good conditions include:

- large amounts of fractures;
- good interconnection between fractures;
- wide, large, clean fractures;
- a source of recharge;
- a large quantity of water in storage; and
- proper installation of the well, including removal of granular debris that may clog the fractures.

Some wells may be dry if the above conditions are not met.

How do you know if you'll get a high-yielding well?

You don't. While exploration of the site may help to assure a high-yield well in fractured rock, you will still face some trial and error that you seldom face when drilling in an alluvial aquifer. Wells that are drilled close together in alluvial aquifers will probably have similar yields. However, wells drilled close together in hard rock may not have similar yields. You have to be able to drill to a very specific point in a major fracture zone that has a lot of water in it. The water must also be continuously recharged. If these conditions aren't met, then you can easily have a dry hole that is drilled right next to a producing well.

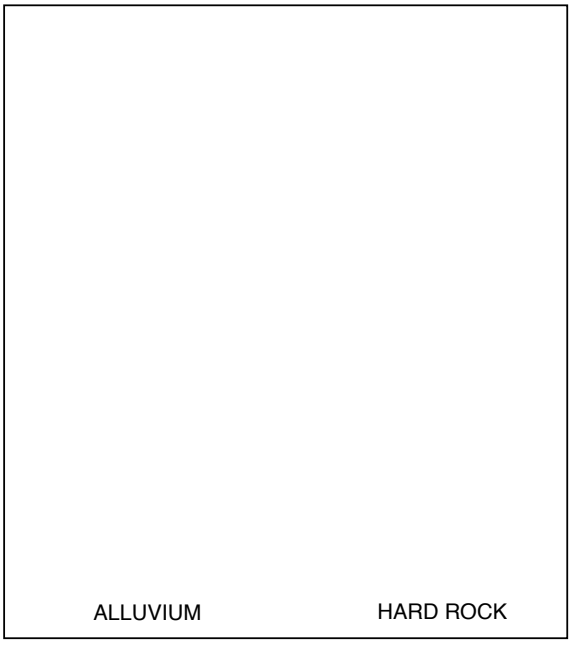
Also, keep in mind that a neighboring well can interfere with your well. How much water passes through fractured rock varies greatly depending on connections between fractures. As a result, interference between neighboring wells is difficult or impossible to predict in advance. The best insurance against such problems is large lot sizes. Wells on lots as large as nine acres have gone dry.

Recent advances such as fracture pattern analysis, borehole imaging, and fracture-flow models have enhanced the field characterization and modeling of fluid flow in fractured rocks, but effective integration of field results and model development remains difficult, because of the highly heterogeneous nature of the fractures within hard rock. Such heterogeneity includes the fracture characteristics listed on this page that control groundwater storage and flow in fractured rock.

How do you get started?

You need a real expert for well drilling, and even that does not assure that you will hit water, but

the odds will be more favorable. If you know a geologist, talk with him or her. Consult a professional well-drilling firm with a California C-57 contractor's license. And remember, once you have your well drilled, pump tests of new wells are necessary to verify the existence of a suitable and sustained water supply. The firm that drilled your well can perform these tests. For a single family residence, 24 hours of pumping and recovery of the water level to within two feet, or 5% of the static level, depending on the amount of drawdown during pumping, may be adequate. Longer tests are necessary for community supply or industrial wells. Consult with your County well permitting agency for specific water well testing requirements for any type of well.



Where do you get more information?

For more information contact any of the following California Department of Water Resources offices, or see our Web site: wwwdwr.water.ca.gov.

Northern District
2440 Main Street
Red Bluff, CA 96080-2398
(530) 529-7300
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Central District
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(916) 227-7590
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San Joaquin District
3374 East Shields Avenue
Fresno, CA 93726-6990
(559) 230-3300
www.dpla.water.ca.gov/sjd

Southern District
770 Fairmont Avenue, Suite 102
Glendale, CA 91203-1035
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wwwdpla.water.ca.gov

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